

BELLCOMM, INC.

1100 Seventeenth Street, N.W. Washington, D. C. 20036

SUBJECT: CSM-LM/ATM Alternate Mission**DATE:** May 6, 1968**FROM:** R. K. McFarlandABSTRACT

The LM/ATM alternate mission, as defined by the present AAP baseline configuration description would be performed with the LM/ATM docked to the AAP-3 CSM, and have a mission duration of 28 days. The mission duration could be increased to 36 days by carrying additional LiOH, and possibly to 56 days with the addition of LiOH and an electrical power interface between the CSM and ATM. Revisit and reuse of the LM/ATM subsequent to the alternate mission is discussed, and major modifications required to the LM/ATM to implement this capability are reviewed.

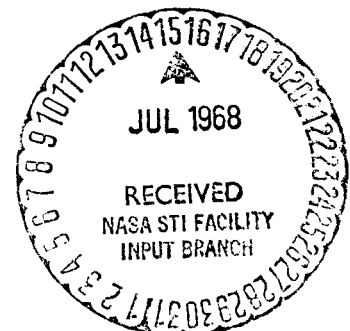
(NASA-CR-95524) CSM-LM/ATM ALTERNATE
MISSIONS (Bellcomm, Inc.) 9 p

N79-71573

Unclas
11207

00/12

| | | |
|----------|-------------------------------|------------|
| FF No. 6 | CR-95524 | |
| | (NASA CR OR TMX OR AD NUMBER) | (CATEGORY) |
| | [REDACTED] | |



BELLCOMM, INC.

1100 Seventeenth Street, N.W. Washington, D. C. 20036

SUBJECT: CSM-LM/ATM Alternate Mission**DATE:** May 6, 1968**FROM:** R. K. McFarlandMEMORANDUM FOR FILE1.0 INTRODUCTION

The LM/ATM portion of the AAP-1 through AAP-4 mission sequence has as an alternate mission a mode of operation whereby the LM/ATM would be operated docked to the AAP-3 CSM. This alternate mission is a contingency mode, and would be flown in the event that the LM/ATM could not be docked to the MDA.⁽¹⁾

This memorandum reviews the logistic constraints on mission duration assuming that no LM/ATM revisit and reuse goal exists for the alternate mission. In addition, revisit and reuse is discussed, reviewing modifications that would be required to the LM/ATM baseline configuration to develop this capability for the alternate mission.

2.0 ALTERNATE MISSION CAPABILITY - NO REVISIT AND REUSE

The alternate mission can be described if mission duration is limited to logistic considerations only; crew volume-duration constraints are not considered in this memorandum. Alternate mission duration capabilities are described for the present baseline configuration, which would be a 28 day mission, and for two alternate mission durations.

2.1 28 Day Alternate Mission

The AAP-3 CSM carries all expendables for the baseline AAP-3/AAP-4 56 day mission, except 1200 lbs of O₂ carried on the LM-A.* However, due to the use of a molecular sieve in the MDA, the CSM carries only a 28 day supply of LiOH for use in the CSM environmental control system. In the event that the alternate mission mode was adopted, this consumable quantity would then limit the mission to 28 days, although all other consumables would be available for a longer mission duration.

2.2 36 Day Alternate Mission

Assuming additional LiOH is made available, the limiting consumable would then become H₂, which is carried as a reactant for the CSM fuel cell power plants (FCPs). The AAP-3 CSM carries fuel cell reactant quantities sufficient to provide approximately 2400 Kwh of electrical power; using study estimates⁽²⁾ of CSM electrical

* Recent changes to the AAP baseline have placed all O₂ in the CSM.

power requirements for the various phases of the AAP-3 mission sequence, an approximate electrical power time-line can be formulated for the alternate mission, as shown in Table I.

CSM electrical power requirements for the baseline AAP-3/AAP-4 mission have been estimated at 2500 watts average during mission operation.⁽²⁾ The alternate mode would require additional electrical power for heaters, due to the complete shadowing of the CSM during ATM operation. Table I indicates mission duration assuming a 2800 watt average CSM electrical power requirement. Thus, the alternate mission could have a duration of approximately 36 days, as limited by the reactants for the CSM FCPs. To attain this duration, 18 additional LiOH canisters would be required, weighing 89 lbs.

2.3 56 Day Alternate Mission

Removing the LiOH constraint, the alternate mission duration is limited by CSM fuel cell power plant reactant quantities. However, if electrical power is made available to the CSM from the LM/ATM electrical power system, the mission duration could be increased, with an upper limit of 56 days. Crew water requirements necessitates a minimum CSM FCP output of approximately 1800 watts average, as prescribed in the baseline mission. Therefore, if sufficient electrical power is provided to the CSM from the LM/ATM to reduce the CSM EPS loads to 1800 watts average, the alternate mission could have a mission duration of 56 days.

LM-A and ATM electrical power requirements are listed in Table II; ATM EPS capability is also shown for beginning of life operation; no radiation degradation to the solar array is considered. With the excess power indicated, the CSM EPS requirements could be reduced from the estimated 2800 watt operating level to 1800 watts, identical to the baseline 56 day mission. As electrical interfaces are specified for the modules in the baseline configuration, the only physical modification required to allow this power transfer would be the provision for compatible umbilical connections between the ATM and the CSM. Power transfer would be as in the baseline configuration, electrical busses would not be paralleled.

To provide LiOH capability for this 56 day alternate mission, 56 additional LiOH canisters would be required, for a net weight of 276 lbs.

All other expendables on the CSM would be sufficient for the 56 day mission, with the possible exception of CSM RCS propellant quantities. If the gravity gradient technique for dumping bias momentum from the ATM pointing control system (PCS) could be used for the CSM-LM/ATM configuration, then the CSM RCS would be required for momentum dumping only during periods of high β angles. If all momentum dumping was performed by the CSM RCS, then approximately 450 lbs of propellant would be required for the 56 day

Table I

AAP-3 CSM Electrical Power Requirements
Alternate Mission

| <u>Event</u> | <u>Kwh</u> | <u>Hours</u> |
|--------------------|------------|-------------------------|
| Pre-launch | | |
| to | 91.1 | 39.0 (10 hr. prelaunch) |
| CSM-LM-ATM docking | | |
| to | 102.8 | 43.3 |
| CSM/LM-ATM staging | | |
| to | 26 | 10.6 |
| CSM/MDA docking | | |
| to | 19 | 8.0 |
| CSM/LM-ATM docking | | |
| to | 2153.65* | 769.2 hrs. (32 days) |
| CSM/LM-ATM staging | | |
| to | 7.45 | 2.41 |
| CM/SM staging | | |
| | <hr/> | <hr/> |
| | 2400 Kwh | 891 (36 days) |

* Assuming CSM electrical power requirements of 2800 watts, average.

Table IILM/ATM Electrical Power Requirements
and Capability

| <u>LM-A</u> (3) | <u>Watts, Average</u> |
|---|-------------------------------------|
| Crew Prov. | 25 |
| D & C | 11 |
| EPS | 81 |
| ECS | 199 |
| Instr. | 50 |
| ATM D & C | (148) delete, shown below |
| Growth | <u>(100) delete</u> |
| | 366 |
| <u>ATM</u> (4) | |
| Expts | 211 |
| D & C (3) | 148 |
| Instr. | 424 |
| Thermal | 700 |
| PCS | 990 |
| Command System | 27 |
| EPS | 133 |
| Distr. Loss | <u>200</u> |
| | 2833 |
| Total LM/ATM | 3199 Watts |
| ATM beginning of life Electrical Power System Capability (5) | 4210 Watts, Average, ($\beta=0$). |
| Net excess electrical power | 1010 Watts. |

mission. The present baseline CSM carries approximately 350 lbs of RCS propellant for CMG dumping, however an additional 350 lbs is allocated for experiment support.

3.0 ALTERNATE MISSION CAPABILITY - REVISIT AND REUSE OF THE LM/ATM

A number of problem areas exist with regard to providing orbital storage and reuse capability for the LM/A, the most pertinent being:

1. Should the LM/A RCS be deactivated prior to orbital storage, and if so, in what manner?
2. What are the thermal balance and heater requirements in the LM/A during orbital storage, and how should the heat transport network be stored?
3. Status monitoring is not considered adequate to determine the condition of the LM-A subsequent to orbital storage. Procedures must be developed to provide preutilization check-out of the LM-A prior to commitment of the reuse mission.

In addition to these problem areas, revisit and reuse of the alternate mission LM/ATM involves problems unique to this concept, which are discussed in the following paragraphs.

3.1 Orbital Storage of the LM/ATM

At the completion of the alternate mission, the LM/ATM would be left in a storage mode for subsequent revisit and reuse. Two possible orbital storage flight attitudes exist for the LM/ATM: a gravity gradient attitude, and an inertial attitude that would be essentially identical to the normal operational mode.

The gravity gradient attitude would not require the use of the ATM PCS; however, the lack of significant asymmetry of the LM/ATM configuration combined with the known destabilizing effects of aerodynamic torque raise doubts on the feasibility of this flight attitude. This factor coupled with the low power output from the ATM EPS would make the gravity gradient attitude very difficult to implement.

3.1.1 Inertial Storage Mode

The most probable flight attitude for the storage mode would be inertial, using the ATM PCS to stabilize the configuration. Full electrical power capability would be obtained from the ATM EPS.

A disadvantage of this flight attitude would be the need for periodic remote momentum dumping, due to the need to point the LM/ATM roll axis out of the orbital plane during periods of high β angle. This condition could be eliminated by solar orienting with ATM PCS, however, leaving the roll axis in the orbital plane. This flight attitude would incur losses in the ATM EPS during high β angle, however, bias momentum accumulation in the CMGs would be minimized. Power output from the ATM EPS would vary from approximately 2500 to 3800 watts average which is more than adequate.

3.2 CSM-LM/ATM Docking

Subsequent to orbital storage of the LM/ATM, a revisit CSM would rendezvous and dock to the LM/ATM. Problems associated with this maneuver are two-fold: maintaining attitude control of the LM/ATM in the event of a miss-dock, and impulsive loads imparted to the LM/ATM in a worst case docking.

3.2.1 LM/ATM Attitude Control

The angular momentum imparted to the LM/ATM from a worst case CSM miss-docking can be computed using specified maximum CSM closing rates: (7)

| | |
|-----------------------------------|-----------|
| relative axial closing velocity | 1 ft/sec |
| relative lateral closing velocity | .5 ft/sec |
| relative initial angle | 10° |
| relative initial angular rate | 1°/sec. |

For the worst case, an angular momentum of approximately 5,000 ft-lb-sec would be imparted to the LM/ATM. If the CMGs are operating, and their momentum vectors are properly directed, it is possible that the LM/ATM could maintain a stable attitude subsequent to the miss-dock, however, an attitude control system would be required to initially position the CMG momentum vectors, and in all likelihood to act as a backup in the event CMG saturation occurred.

3.2.2 Impulsive Loads

The LM/ATM would, by present design, have the solar panels extended during the revisit docking of the CSM. The worst case docking would impart a linear impulse of approximately 650 lb-sec, with an initial axial excitation frequency at about 1 cps. This excitation frequency lies near the 2nd natural frequency of the extended solar arrays, as such, structural damage to the arrays could result from the docking impact.

This loading condition could be avoided by retracting the solar arrays, or redesigning the array support structure.

4.0 SUMMARY

The present baseline LM/ATM program, if operated in the alternate mode, would have a mission duration of 28 days. This mission would be limited by the quantity of LiOH carried in the AAP-3 CSM.

If 18 additional LiOH canisters are carried in the CSM, the alternate mission duration would be approximately 36 days; the limiting factor for this mission duration would be H₂ for the CSM FCPs.

If an electrical power interface is provided between the CSM and ATM, excess electrical power from the ATM EPS could be provided to the CSM, and the alternate mission would have a duration of 56 days. However, 56 additional LiOH canisters would be required, for a weight increase of 276 lbs.

If a revisit and reuse capability for the LM/ATM is required for the alternate mission, the LM/ATM will require an augmented or alternate attitude control system. In addition, the ATM solar arrays will have to be retractable, or the array structure redesigned to accommodate the CSM docking loads.

5.0 CONCLUSIONS

The adoption of a revisit and reuse capability for the alternate mission would incur costly modifications to the LM/ATM and add complexity to the configuration. The logic of providing a revisit and reuse capability for the alternate contingency mission is questioned, particularly since the modifications required would not improve the capability of the LM/ATM in the baseline mission.

The addition of at least 90 lbs of LiOH to the baseline configuration to provide an additional 8 days of alternate mission capability appears to be a very small penalty for the added duration in the contingency mode. The question of providing for alternate mission durations beyond 36 days would of necessity be governed by the desire for an extended duration contingency mission. The limited crew volume available in the CSM-LM/ATM would be a factor that would be considered before committing the additional weight of LiOH that would be required. However, as the modifications required to obtain the extended duration are minor, the open-ended mission concept that could result would allow the alternate mission to continue until mission termination was dictated by factors other than the need for a few pounds of LiOH.

BELLCOMM, INC.

References

1. Baseline Configuration Definition AAP-1a through AAP-5, Apollo Applications Program, December 6, 1967.
2. Apollo Applications Program - Trade-Off Study - CSM Power Sources, NAR, SD 67-842, October 27, 1967.
3. 6th AAP Electrical Panel Meeting, March 26 - 27, 1968, Item 5-17 and 5-18.
4. ATM Electrical Power System Review, October 30, 1967.
5. 5th AAP Electrical Panel Meeting, January 25, 1968.
6. AAP/LM-A Management Meeting, January 10, 1968.
7. CSM/LM Structural Loads and Bending Moments, NAA-ICD, MH-01-05050-414.